FISH AND DECAPOD CRUSTACEA IN ALTERED AND UNALTERED STREAMS ON THE ISLAND OF HAWAI'I

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ABSTRACT

In 1975-1976 and 1978-1979, field work was conducted along the Hāmākua and North Kohala coasts to obtain much-needed baselines for evaluating future stream alteration proposals as well as ecological information applicable to the protection and preservation of native Hawaiian fauna.

Six (5%) of the Big Island's 123 perennial streams were found altered. Four types of channel modifications were distinguished: (1) lined channel where an artificial (concrete) channel replaces both natural banks and stream bed; (2) vegetation removed-channel realigned; (3) elevated culvert; and (4) revetment where both banks are reinforced but channel bed is not.

Fish and decapod crustacea collections were made with battery-energized backpack shockers in four altered and eight unaltered streams. All specimens collected from a 20 m X 1 m quadrat were identified, counted, and released in the same vicinity.

Fourteen species were collected, eight (57%) of which are native to Hawai'i. These are goby and goby-like fish--'o'opu-'alamo'o, 'o'opu-nākea, 'o'opu-naniha, 'o'opu-nōpili, 'o'opu-'ōkuhe; perch-like fish--āholehole. The native crustaceans are: 'ōpae-kala-'ole, 'ōpae-'oeha'a. Analysis showed more introduced species in altered streams. Population densities of both native and introduced species are higher in unaltered streams. A trend was established whereby stream alteration favored introduced species and depressed densities of both fish and decapod crustaceans.

INTRODUCTION

Perennial streams represent the principal freshwater environment and habitat for native Hawaiian animals. The Hawaiian stream fauna is unique and its geographic range and sizes of populations are limited. A large fraction of the conspicuous native stream animals occur naturally nowhere in the world except in these limited fragile stream habitats. Almost all of these species are obligately diadromous, meaning that they spend part of their life cycle (usually the larval period) in salt water. For these animals to complete their life cycle, therefore, suitable pathways from the ocean to their places of permanent residence must be present. In spite of the importance of perennial streams and their importance to the well-being of endemic animals, no comprehensive list of streams nor descriptive inventory of stream channel alterations as well as the resident animals, has existed before this survey.

Threats to the integrity of stream ecosystems come from three principal cultural changes. First, there is a continued demand for more housing space to accomodate an ever-growing population. When houses are built in a stream's flood basin the lower reaches of stream channels are altered to prevent flooding. Second, this ever-growing population needs additional water for agricultural and domestic uses and sometimes for recreation as well. Thus, more and more water ends up being exported from the stream's drainage basins. Third, the introduction, whether by design or by accident, of exotic species have a profound effect on the native animals. Exotic species aggressively compete with the native species for food and space. In some cases, exotic species prey on the native animals as well.

This paper deals with the first of three cultural changes: stream channel modifications. Its purpose is to compile an inventory of perennial streams, types and extent of stream channel modifications, and fishes and decapod crustaceans found in altered and unaltered streams.

The study area is on the Hamakua and Kohala coasts where most of the Hawai'i Island streams are located. Those areas receive the highest rainfall on the Island. The lowlands receive between 165 and 355 cm of rain, mountain slopes between 380 and 700 cm, and the high mountains between 150 and 205 cm (Taliaferro 1959). This paper is a re-analysis and refinement of portions of two studies: Channel Modification in Hawaii (Timbol & Maciolek 1978) and Lentipes concolor Survey (Timbol, Sutter, & Parrish 1980). The influence of co-workers on the direction of the original studies and their efforts are acknowledged with appreciation. Field work was done in 1975-1976 and 1978-1980.

METHODS

For purposes of this report, a stream is defined as surface water flowing in a discrete channel or channel system that discharges to the ocean at a single point. Thus, a given stream may have a single dominant channel or a complex of branching tributaries. Two classes of perennial streams are distinguished: the first are continuous streams which flow naturally to the sea year-round under natural conditions; and the second are interrupted streams which have ecologically significant perennial water in their upper water courses and intermittent flow in their channels at low elevations. Interrupted streams discharge into the sea occasionally during the wet seasons.

Stream Survey

A list of streams was prepared from USGS quadrangle maps. Channel modifications were identified from field surveys and from the 1975 Real Estate Atlas. Total lengths of altered streams were estimated by measurement of the watercourses drawn on the USGS topographic maps (scale 1:24,000) using a Keuffel & Esser Co. (K & E) map measurer. Lengths of altered channel sections were also measured in the same way or taken from the 1975 Real Estate Atlas when available, and field checked.

Biological Methods

Collections of fishes and decapod crustaceans were made with battery-energized backpack electroshockers. Electrofishing was employed because it is the most effective (Maciolek & Timbol 1980) and quickest method of sampling principal stream animals: fishes and decapod crustaceans. In most cases, collections from a given stream were made at three locations: in altered streams --in the freshwater portion nearest to the mouth, within the altered channel, and upstream from channel modification; in unaltered streams--in about comparable locations as in the altered streams. All specimens collected from a 20 m X 1 m sampling site were identified and counted. Because collections were made in small sections of channel, usually in lower stream reaches, faunal inventories do not represent full species complement or distribution of fishes and crustaceans in the entirety of any given stream.

Abundance and distribution data are given in relative terms as abundant, common, uncommon, and absent. For purposes of this report: abundant (+++) means many individuals (from six to 100 or more) were caught in a standard 20 m X 1 m sampling quadrat; common (++) indicates that between two and five individuals were caught; uncommon (+) means that only one individual was obtained, or sighted but not caught; and if a species was neither collected nor seen, it was probably absent (0).

Terms used in the text are: "threatened" which includes those species which are endangered, depleted, or rare. "Endangered" species include those which may be locally abundant but with a highly restrictive distribution, or those which occupy much of their former range but in greatly reduced numbers (Bovee & Cochnauer 1977). "Depleted" indicates the species is still found in numbers adequate for survival but has been heavily depleted and continues to decline substantially (Miller 1972). "Rare" means uncommon, occurring in small numbers. "Special concern" is a category reserved for those species that could become threatened or endangered by relatively minor disturbances in their habitat, or that require additional information to determine their status (Deacon et al. 1979).

RESULTS

Perennial Streams, Altered Streams, & Channel Modifications

A total of 123 perennial streams have been recognized on the island of Hawai'i. One hundred and twenty of these are along the Hāmākua and Kohala coasts. Six (or 5% of total) were found altered. The features of these altered streams are summarized in Table 1. Among these altered streams, Wailoa River in the Puna District is the largest on the basis of channel length. Lanimaumau Stream, north of Kamuela, is the smallest.

The six altered streams had a combined total of approximately 4.5 km of modified channels, averaging 6% (range 0.4-12.0%) of their combined channel length. The relative "abundance" of each type of channel modification expressed as a percentage of the 4.5 km total is as follows:

1. Lined channel (44%). This is an artificial channel having both natural banks and stream bed replaced, usually with concrete. It may be flat bottomed or v-shaped. Alenaio and Waiākea tributaries of Wailoa River; Kaawalii Stream in Kūka'iau; and Lanimaumau Stream in Kamuela are examples of this type of alteration.

2. Cleared and/or realigned (31%). In this type of channel modification riparian vegetation is removed and/or the channel is realigned. This type is found in the Waiākea tributary of Wailoa River; upstream of the concrete-lined channel on Kinoole and Mohouli streets in Hilo; and Waimaauou Stream in Pepe'ekeo.

3. Revetment (23%). One or both banks of the stream are reinforced but the channel bed is not, as in Waialama Canal leading to the Wailoa River in Hilo and Papuaa Stream in Honoka'a.

4. Elevated culvert (2%). This is a conduit structure that is comparatively short (typically < 60 m), usually found under highways. Culverts placed in this category include only those in which the culvert level is well above the water level immediately

downstream, i.e., the culvert created an artificial waterfall as in Pukihae Stream, just outside of Hilo.

Biological Collections

Biological collections were made in 12 streams in Puna, South Hilo, North Hilo, and North Kohala districts. Four of these streams (Pukihae, Wailoa River, Lamimaumau, and Waimaauou) are altered but only Wailoa River and Lamimaumau Stream have been significantly altered. The eight unaltered streams ('A'amakāō, Honoli'i, Kolekole, Niuli'i, Paheehee, Peleau, Wailuku, and Waikama) are representative of Hawai'i streams having continuous strong waterflow through deeply eroded, heavily vegetated gulches.

Results indicate at least 14 species of fishes and decapod crustaceans were collected: 11 fishes and 3 crustaceans. A list of the organisms is give in Table 2, including common/Hawaiian names, their status, and whether or not any of them is listed as threatened or endangered on the 1977 Federal List of Endangered Species or any other scientific publications. Of the 14 species, five fish species and two crustaceans are endemic, one fish is indigenous, and the rest are introduced. None of these organisms is on the official register of Threatened and Endangered Species (USFWS 1977). However, three endemic gobiids are listed on the American Fisheries Society (AFS) List of Threatened Fishes (Miller 1972; Deacon et al. 1979). The AFS listed Lentipes concolor J. & E. as rare and endangered (Miller 1972) but later downgraded it to threatened (Deacon et al. 1979). Maciolek (1977) has recommended that L. concolor be recognized as endangered; the Hawaii State Division of Fish and Game (HSFG) has opposed such a move (HSFG correspondences to the AFS dated 1 Oct. 1978 and 8 Oct. 1978). Awaous stamineus J. & E. was listed as depleted by the AFS in 1972 (Miller 1972); it was downgraded to special concern in 1979 (Deacon et al. 1979). A third goby, Sicydium stimpsoni Gill, was considered depleted on O'ahu in 1972 (Miller 1972). It was downgraded also to special concern in 1979 (Deacon et al. 1979).

Relative abundances of fishes and decapod crustaceans found in altered and unaltered streams are summarized in Table 3. Results are averages of catch data for each group of streams. There were no significant differences in the number of species in altered and unaltered streams. However, population density of native stream macrofauna was higher in unaltered streams than in altered ones. The population densities were high for Sicydium stimpsoni, especially in unaltered Niuli'i and Waikama streams, and average for Awaous stamineus and Lentipes concolor. In one unaltered stream (Peleau) the only fish present was L. concolor, the rarest of the three gobiids. A later survey (Timbol, Sutter, & Parrish 1980) indicated that Peleau Stream was the only stream on the Island where Lentipes was in some abundance. The indigenous Awaous genivittatus J. & E. was of average density and is a prominent resident of the Waiakea pond (Wailoa River).

The native crustaceans Atya bisulcata Randall and Macrobrachium grandimanus Randall; the introduced crustacean M. lar (Fabricius); and the introduced wild guppy Poecilia reticulata were widespread. The introduced loach, Misgurnus anguillicaudatus, and the introduced swordtail, Xiphophorus helleri, were collected in Wailuku River. The moonfish, X. maculatus, was collected only in the Waialama Canal (Wailoa River) in Hilo.

DISCUSSION

This survey has shown only that more exotic species were found in altered streams than in unaltered streams. No attempt was made to determine why this was so. Another study (Norton, Timbol, & Parrish 1978) was made for purposes of describing the effects of channel modifications (i.e., lined channel) on macrofaunal communities. It showed that environmental conditions in the altered streams were more variable than in the unaltered streams. Even within the altered streams, environmental conditions were less stable in lined channels than in natural channels. It was also found that introduced species were able to withstand highly variable environmental conditions. This explained why introduced species replaced native stream species in altered streams, especially within and near the modified channels.

The effects of observed levels of environmental variability in altered streams on native Hawaiian stream animals (e.g., gobiids and crustaceans) were also studied (Hathaway 1978). In the study conducted by Norton, Timbol, and Parrish (1978) it was found that temperature was a major factor influencing the distribution of fishes and crustaceans. Hathaway (1978: 18) obtained water temperature ranges between 21.3°C and 36.2°C at 1400 to 1500 hours in concrete lined channels. Laboratory studies subjecting endemic gobiids (Awaous stamineus, Sicydium stimpsoni, & Lentipes concolor) in elevated water temperatures found that 50% (LD_{50}) of the gobiids died in the vicinity of 36°C. On the other hand, the LD_{50} temperature for introduced fishes frequently found in altered streams, such as Poecilia, was 41°C. This explained the predominance of introduced species in altered streams.

These observations are not confined to tropical, insular streams such as those in Hawai'i. Gebhards (1973) estimated that channel alteration reduced game fish production in trout streams in Idaho by 87%, in North Carolina streams by 76%, in Missouri by 79%, and in Montana by 90%.

SUMMARY AND CONCLUSIONS

There are 123 perennial streams on the Island of Hawai'i. Six (or 5% of total streams) were found with some type of channel modification. Four types of channel modifications were recognized: lined channel, cleared and/or realigned, revetment, and elevated culvert. Wailoa River in Hilo and Lanimaumau Stream in Kamuela were found to be heavily altered.

A total of 14 species of fishes and decapod crustaceans were found: 11 fishes, 3 crustaceans. None of these is listed as threatened or endangered on the 1977 Federal List of Endangered Species but three are listed in the American Fisheries Society List of Threatened Species.

Altered streams were found to harbor more species than unaltered ones. In addition, there were more introduced species in altered streams. On the other hand, abundances were lower in these altered streams.

A trend has been established whereby stream channel modifications favor introduced species but depress fish and decapod crustacean abundances.

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TABLE 1. Altered streams on the island of Hawai'i showing length, type, and location of channel modification.

Stream: Map Location Grid Coordinates	Length of Channel (km) Total	Modified	Type of Alteration	Location of Alteration[1]
1. Wailoa R.: Hilo 19°43'36", 155°04'25"	26	3.2	lined, realigned, revetment	0.8
2. Pukihae: Hilo 19°44'09", 155°05'30"	16	0.1	elevated culvert	<0.1
3. Kaawalii: Kūka'iau 20°00'31", 155°15'53"	22	0.1	lined	0.5
4. Waimaauou: Pāpa'ikou 19°50'00", 155°05'12"	6	0.5	realigned	2.3
5. Papuaa: Honoka'a 20°06'12", 155°28'12"	5	0.1	elevated culvert, revetment	2.5
6. Lanimaumau: Kamuela 20°00'56", 155°40'25"	5	0.5	lined	16.5

[1] Distance of modified channel from stream mouth (km).

TABLE 2. List of fishes and decapod crustaceans in perennial streams on the island of Hawai'i.

Scientific Name	Common/Hawaiian Name[1]	Status	Listing[2]
CRUSTACEANS			
Atya bisulcata	'Ōpae-kala'ole	Endemic	None
Macrobrachium grandimanus	'Ōpae-'oeha'a	Endemic	None
M. lar	Tahitian prawn	Introduced	None
FISHES			
Awaous genivittatus	'O'opu-naniha	Indigenous	None
A. stamineus	'O'opu-nākea	endemic	Depleted on O'ahu[3] Special concern[4]
Eleotris sandwicensis	'O'opu-okuhe	Endemic	None
Gambusia affinis	Mosquitofish	Introduced	None
Kuhlia sandvicensis	Āholehole	Endemic	None
Lentipes concolor	'O'opu-'alamo'o	Endemic	Rare and endangered[3] Threatened[4]
Misgurnus anguillicaudatus	Dojo, loach	Introduced	None
Poecilia reticulata	Wild guppy	Introduced	None
Sicydium stimpsoni	'O'opu-nōpili	Endemic	Rare on O'ahu[3] Special concern[4]
Xiphophorus helleri	Swordtail	Introduced	None
X. maculatus	Moonfish	Introduced	None

[1] Hawaiian names are from Pukui and Elbert (1971).

[2] Considered as threatened, endangered, depleted, rare, or meriting special concern in official register or scientific publications.

[3] Miller (1972).

[4] Deacon et al. (1979).

TABLE 3. Distribution and abundances of fishes and decapod crustaceans in altered and unaltered streams on the island of Hawai'i.

STREAM FAUNA Status Scientific Name	Altered	Unaltered
CRUSTACEANS		
Native		
Atya bisulcata	0	+++
Macrobrachium grandimanus	++	+++
Introduced		
Macrobrachium lar	++	+++
FISHES		
Native		
Awaous genivittatus	++	0
A. stamineus	+	++
Eleotris sandwicensis	++	++
Kuhlia sandvicensis	++	+
Lentipes concolor	+	++
Sicydium stimpsoni	+	+++
Introduced		
Gambusia affinis	+	0
Misgurnus anguillicaudatus	+	0
Poecilia reticulata	+++	+++
Xiphophorus helleri	++	0
X. maculatus	+	0

+++ = abundant (6-100 or more were caught in a standard 20 m X 1 m sampling quadrat)

++ = common (between 2 & 5 individuals were caught)

+ = uncommon (only 1 individual was obtained, or sighted but not caught)

0 = absent (the species was neither collected nor seen)